Work, Energy and Power

PHY 1010

Wind energy being converted to electricity.

Content

- Concept of Energy
- Work
- Kinetic and Potential energy
- Power
- Conservation of Energy
- Energy flow in nature

Introduction – Concept of Energy

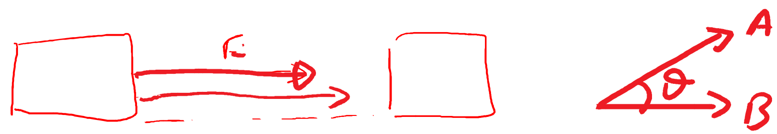
- The concept of energy is one of the most important topics in science and engineering.
- In everyday life, we think of energy in terms of fuel for transportation and heating, electricity for lights and appliances, and foods for consumption. However, these ideas do not really define energy.
- They merely tell us that fuels are needed to do a job and that those fuels provide us with something we call energy.
- How about the energy in our muscles, where does it come from? Did your body create them?

Work

- The word work has a variety of meanings in everyday language. But in physics, work is given a very specific meaning to describe what is accomplished when a force acting on an object moves through a distance.
- When you sit at your desk studying these notes, you are not doing any work! Imagine that?
- This does not mean that you are lazy or that learning physics is an effortless process. It is simply stating a fact that arises from the definition of work that scientists use.

Definition of work

$\vec{A} \cdot \vec{B} = A\,B \cos\theta$ vector dot prod.

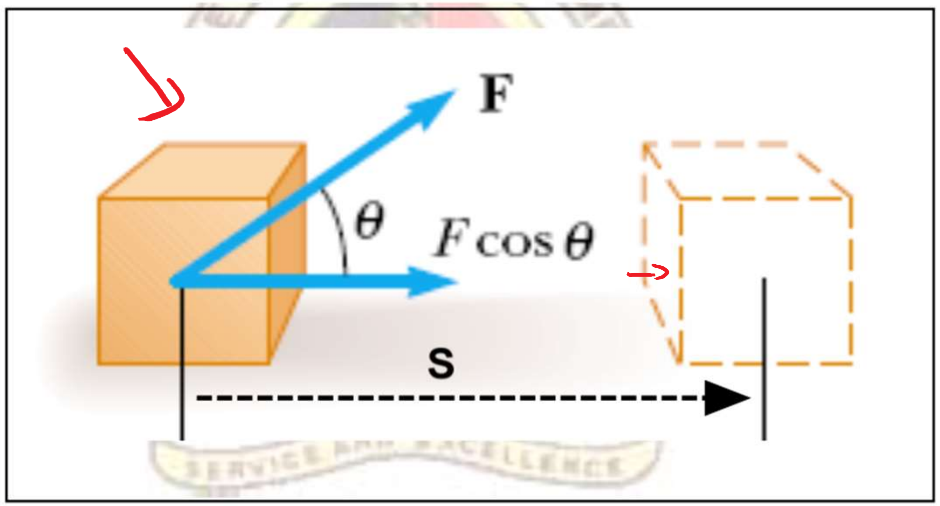


- In physics, the definition of work is the application of a *force through a distance*

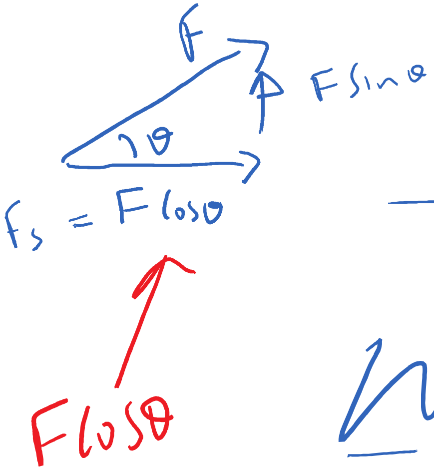
$W = F \cdot d$

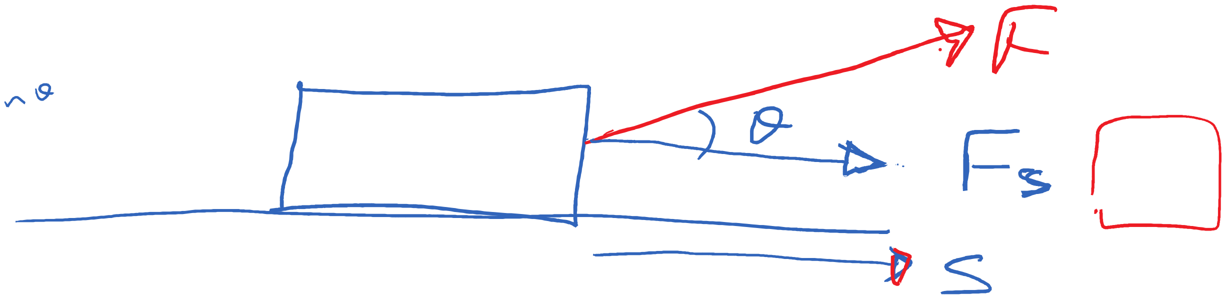
$W = F \times d$
$= Fd$

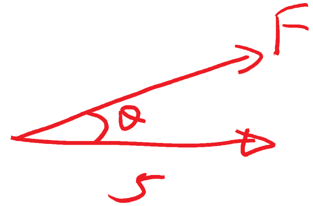
- *W* is the *work* done
- *F* is the *force* applied
- *d* is the *distance* through which the force acts
- Only the force that acts in the direction of motion counts towards work



Note we are using **s** or **d** for distance.







$$W = F_s \times S$$

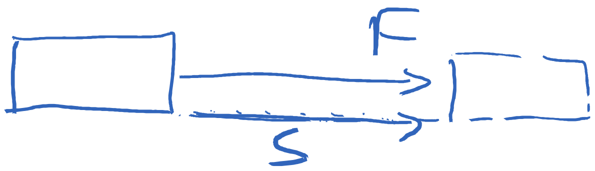
$$= F\cos\theta \times S$$

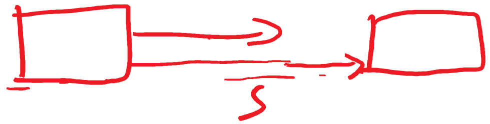
θ = angle btn F and S

$$\boxed{W = FS\cos\theta}$$

General eqn.

$\theta = 0$ ✓





$$W = FS\cos\theta$$
$$= FS\cos 0$$

$\boxed{W = FS}$ Force in the direction of distance
displacement

Because $\underline{\cos 0} = 1$

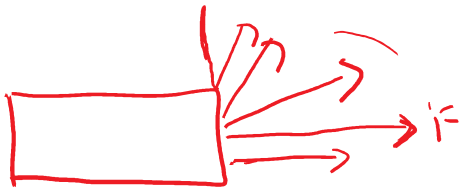
$$\boxed{W = FS}$$

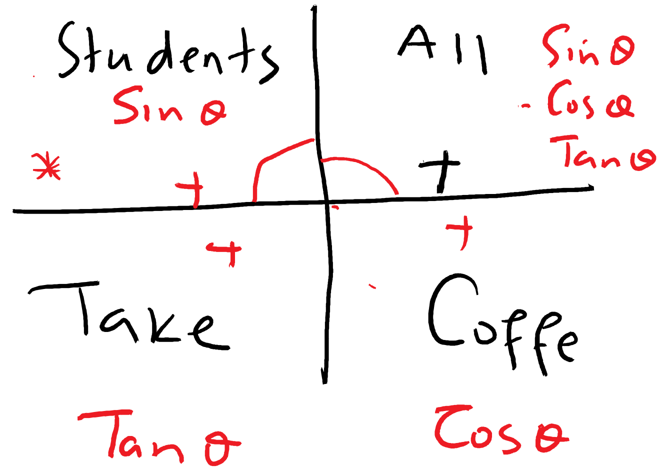
Our general eqn: $\boxed{W = FS\cos\theta}$

Angle between work and distance

1. The presence of θ implies that work can be either be positive or negative

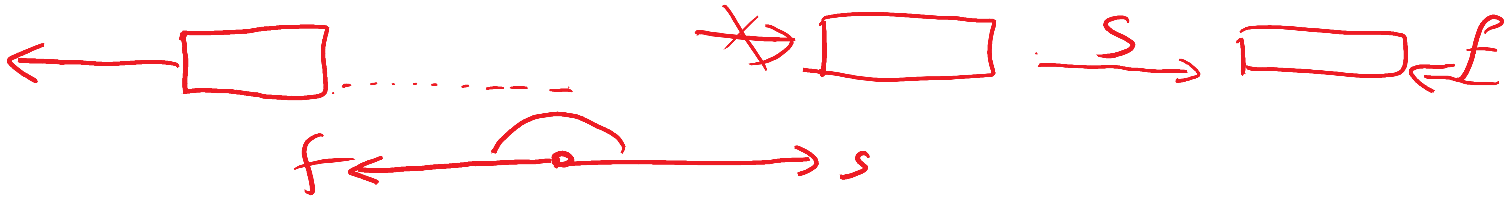
$$W = F s \cos\theta$$





$0 \le \theta < 90$ — work is +ve

$90 < \theta \le 180$ — work is −ve



$$90 < \theta \leq 180^\circ \quad - \quad \cos\theta = -1$$

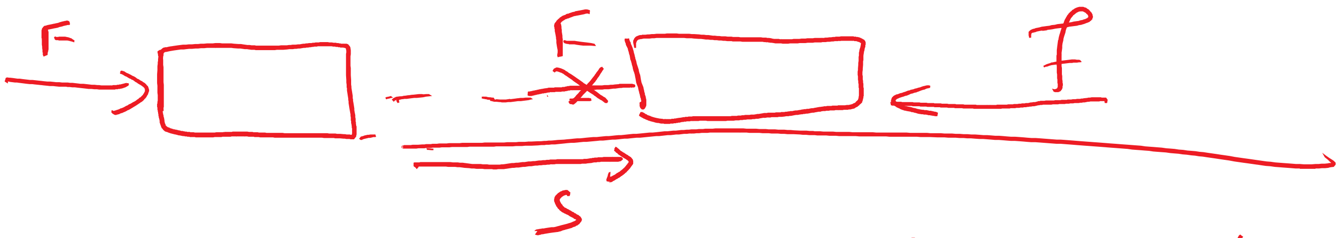
$$W = FS\cos\theta$$

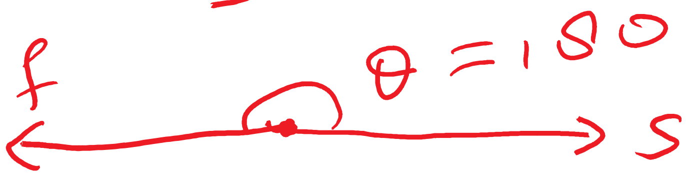
$$= FS(-1)$$

$$= -FS$$

Work is negative

Example.





$\therefore \quad W = -FS$

work done by friction is negative

Energy $\propto$ Work

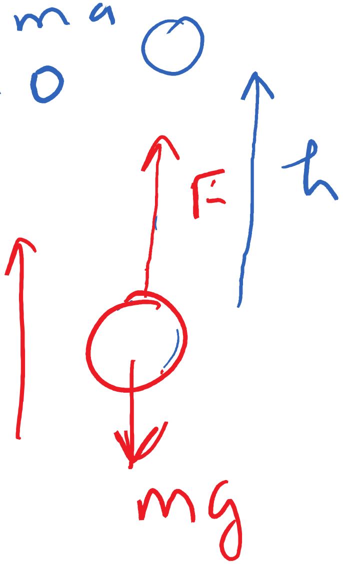
Energy $\xrightarrow{\text{does}}$ Work

$F - mg = ma$

$F - mg = 0$

$F = mg$

Const



$F = mg$

$W = FS\cos\theta$

$= mgh\cos 0$

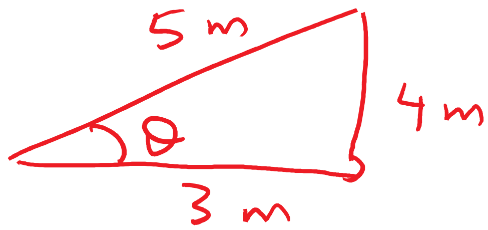
$\boxed{W = mgh}$

Units of Work and Energy

- **Force is a mass times an acceleration**
  - mass has units of kilograms
  - acceleration is m/s^2
  - force is then $kg \cdot m/s^2$, which we call Newtons (N)
- **Work is a force times a distance**
  - units are then $(kg \cdot m/s^2) \cdot m = kg \cdot m^2/s^2 = N \cdot m =$ Joules (J)
  - One joule is one Newton of force acting through one meter
  - Imperial units of force and distance are pounds and feet, so unit of energy is foot-pound, which equals 1.36 J
- **Energy has the same units as work: Joules**

Units for work & Energy.

$$W = \underbrace{F}_{N}\;\underbrace{S}_{m}\;\underbrace{\cos\theta}_{\text{no unit}}$$



$$\cos\theta = \frac{3\cancel{m}}{5\cancel{m}} = 3/5$$

$$W = Nm = kg\,m/s^2 \cdot m = \boxed{kg\cdot m^2/s^2}$$

Joule (J)

$$F = \underbrace{m}_{kg}\;\underbrace{a}_{m/s^2} = kg\,m/s^2 \equiv N$$

Example:

A ~~2st~~ pale of mass m is being lifted up at constant speed through a height of h.

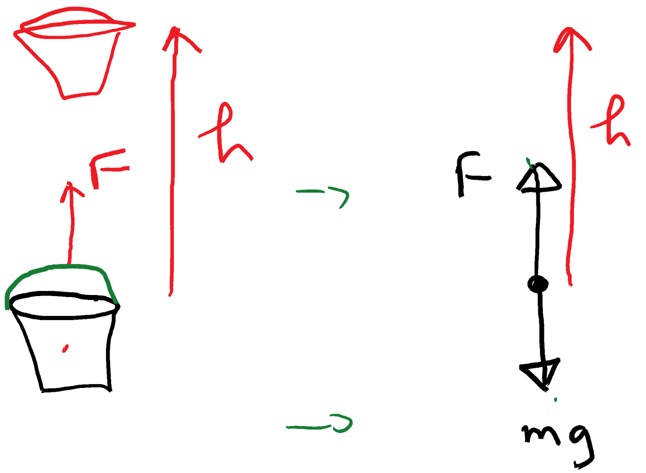
a) Calculate the work done by force

b) Calculate the work done by gravity

$$F - mg = m\overset{0}{\underset{\parallel}{a}}$$

$$\boxed{F = mg}$$

$\theta = 0$

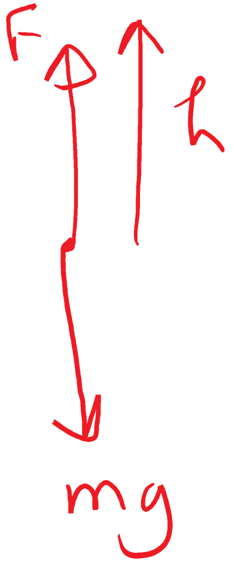


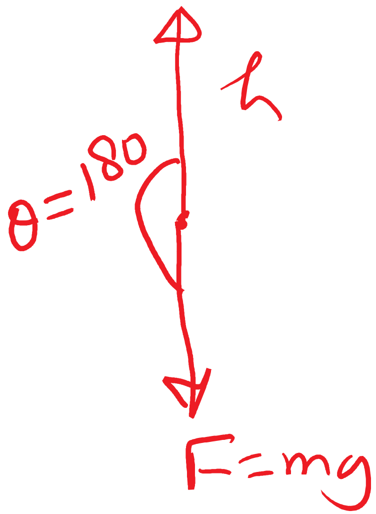
a) $W = FS\cos\theta = mgh\cos 0$

$W = mgh$

The force does +ve work on the object

b)





$$W = FS\cos\theta$$

$$= mgh\cos 180$$

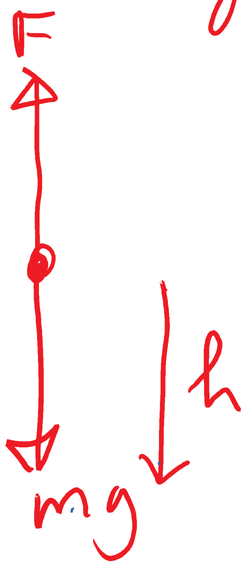
$$\boxed{W = -mgh}$$

gravity does negative work on the object.

$$\cos 180 = -1$$

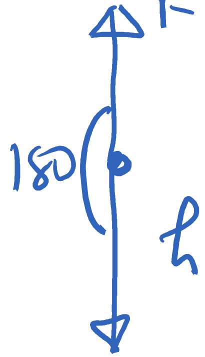
Ex 2

If you lower the pole, at constant speed, Force does negative while gravity does positive on the object.



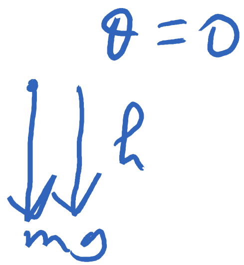
Work by the force

$$W = F S \cos\theta$$
$$= mgh \cos 180$$
$$= -mgh$$



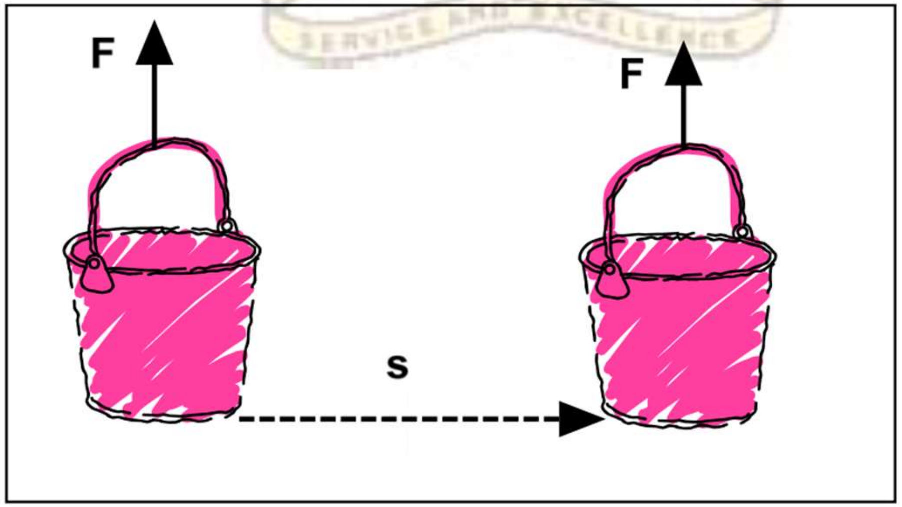
Work done by gravity

$$W = F S \cos\theta$$
$$= mgh \cos 0 = mgh \quad (+ve)$$



Examples

EXAMPLE 6.1: A person carries a pail containing water over a horizontal distance of 8.0 m at constant speed. How much work does *F* do?



Work ?

$$W = Fs\cos\theta$$

$$= Fs\cos 90$$

$$= Fs(0)$$

$$= 0$$

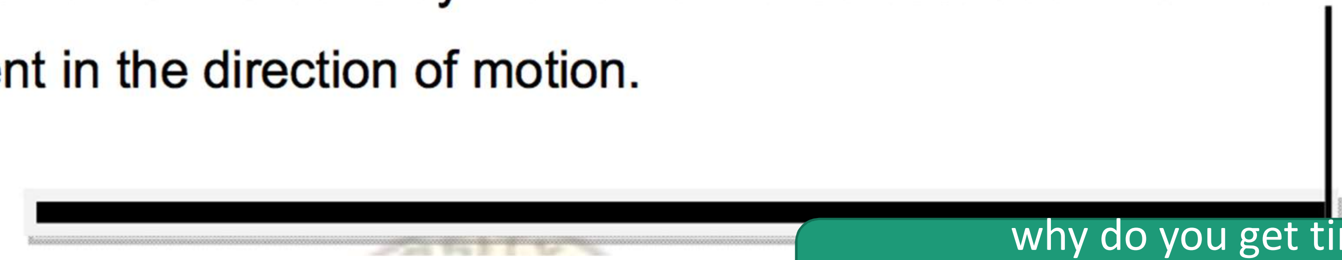
Example

The force *F* is just the weight of the pail plus water. The angle between the F and the displacement vector is 90º (since he was carrying it over a horizontal distance) Therefore work is

$$W = Fs\cos 90° = 0$$

Therefore no work is done by the vertical force because it has no component in the direction of motion.

Remember Newtons 3rd law? The weight of the pail (directed down) is equal to F which is directed up



why do you get tired carrying the bucket even if you do no work?

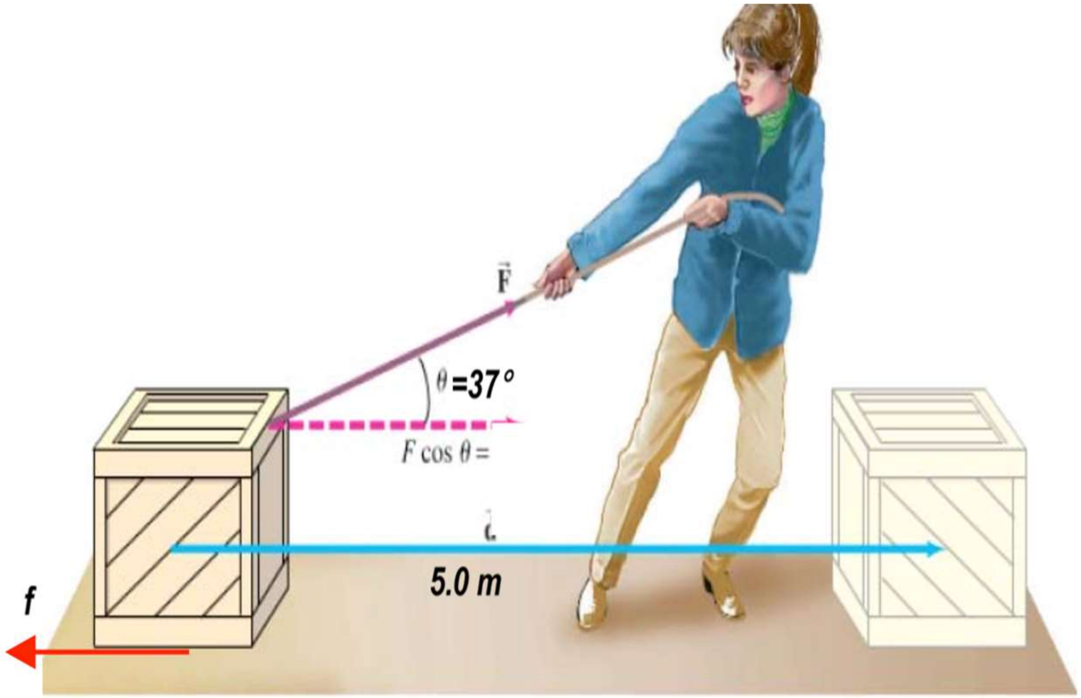
Example

- The box is being pulled along the floor at a constant speed by a force F. The friction opposing the motion is 20 N and m = 30 kg.

Find

a) the magnitude of F and

b) the work done by F as the box is being moved a distance 5.0 m.



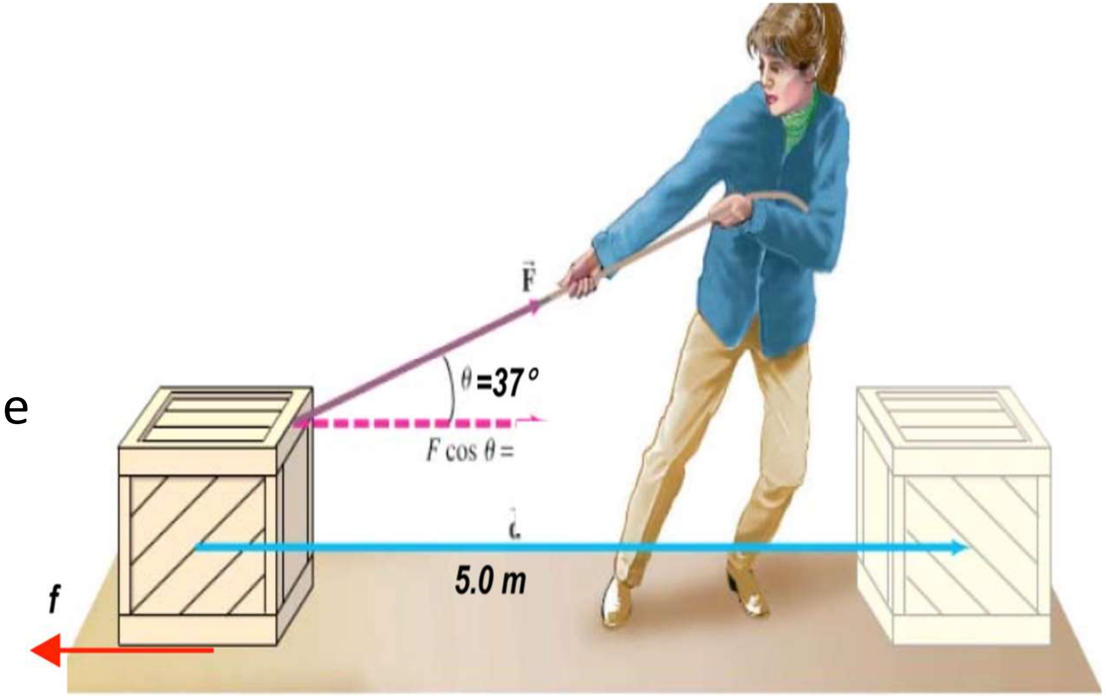
Example

Solution:
We first use Newtonis second law to find the force:

$Fcos37 - 20 = ma = m(0) = 0$ (a=0 because its constant velocity)

Therefore $F = \frac{20}{cos37} = 25$ N

Work: $W = Fscos37 = 25 \times 5 \times cos37 = 100\ \ N$



Kinetic Energy

- If an object can do work, we say it possesses energy. Therefore energy is the ability to do work. There are many types of energy but we shall for begin our study with kinetic energy.

- What is **kinetic energy?**
  When you hear the word *kinetic*, what comes into your mind? No doubt it is something to do with *moving.* Indeed **kinetic energy, KE, of an object is the energy possessed due to its motion.**

Kinetic Energy

Kinetic Energy

- **Kinetic Energy: the energy of motion**
- **Moving things carry energy in the amount:**

$$K.E. = \frac{1}{2}mv^2$$

- **Note the v^2 dependence—this is why:**
  - a car at 60 mph is 4 times more dangerous than a car at 30 mph
  - hurricane-force winds at 100 mph are much more destructive (4 times) than 50 mph gale-force winds
  - a bullet shot from a gun is at least 100 times as destructive as a *thrown* bullet, even if you can throw it a tenth as fast as you could shoot it

Numerical examples of kinetic energy

- A baseball (mass is 0.145 kg = 145 g) moving at 30 m/s (67 mph) has kinetic energy:

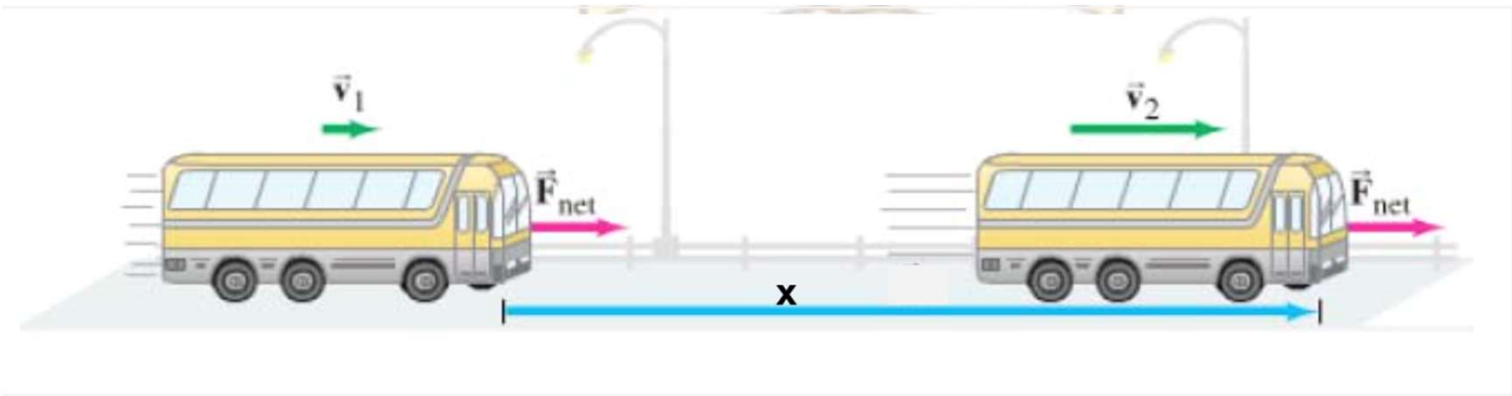
$$K.E. = \tfrac{1}{2}\times(0.145\ \text{kg})\times(30\ \text{m/s})^2$$
$$= 65.25\ \text{kg}\cdot\text{m}^2/\text{s}^2 \approx 65\ \text{J}$$

- A quarter (mass = 0.00567 kg = 5.67 g) flipped about four feet into the air has a speed on reaching your hand of about 5 m/s. The kinetic energy is:

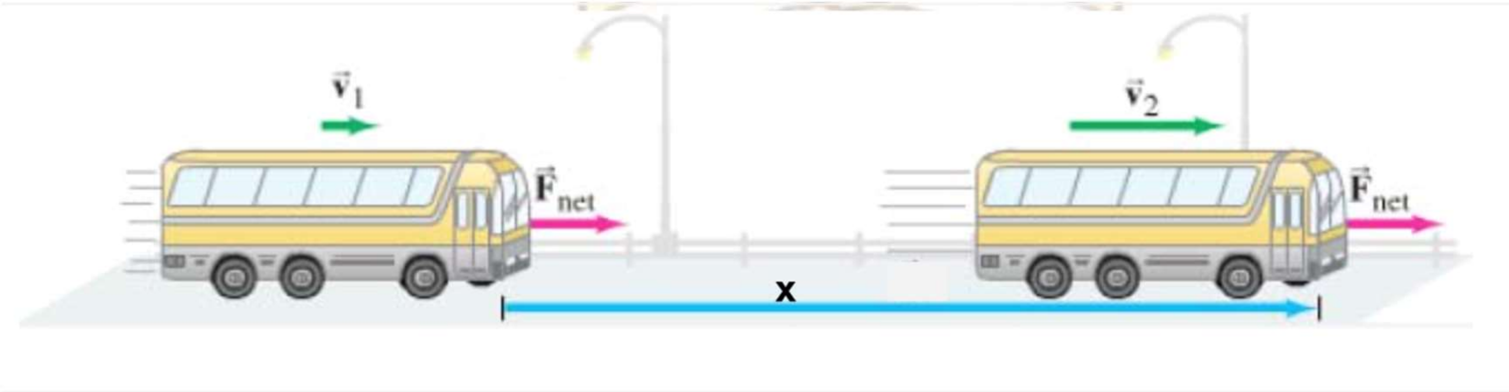
$$K.E. = \tfrac{1}{2}\times(0.00567\ \text{kg})\times(5\ \text{m/s})^2$$
$$= 0.07\ \text{kg}\cdot\text{m}^2/\text{s}^2 = 0.07\ \text{J}$$

Work Energy Theorem

- When an object is acted upon by a net force, it changes speed . Therefore when you apply a net force on an object initially at rest, it moves. There is therefore a connection between the net force and the kinetic energy.



Work Energy Theorem



- Now consider a bus whose engine drives it with a net force so as to accelerate the bus from a speed of v_1 *to a speed of* v_2.
- The net force is given by
- $F_{net} = ma$
- From $v_2{}^2 = v_1{}^2 + 2as$

$a = \frac{v_2{}^2 - v_1{}^2}{2s}$ substituting into above gives

- $F_{net} = m\frac{v_2{}^2 - v_1{}^2}{2s}$ This reduces to

- $F_{net}s = \frac{mv_2{}^2 - mv_1{}^2}{2}$ = $\frac{1}{2}mv_2{}^2$-$\frac{1}{2}mv_1{}^2$

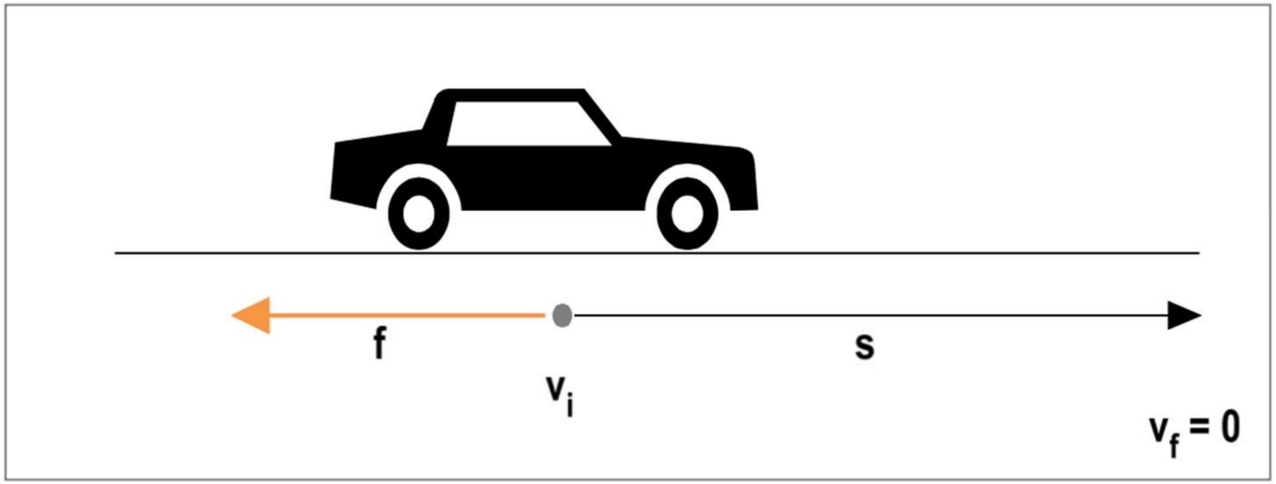
- In other words
- Work (by net force) = change in Kinetic energy

This is the work done by a net force. This is called the **work-energy theorem**

EXAMPLE 6.3: A 1000 kg car travelling at 20 m/s coasts to rest on level ground in a distance of 100 m. How large is the average frictional force acting on the car?

SOLUTION

There is no other force acting on the car apart from friction. Here is the FBD along with the displacement vector.



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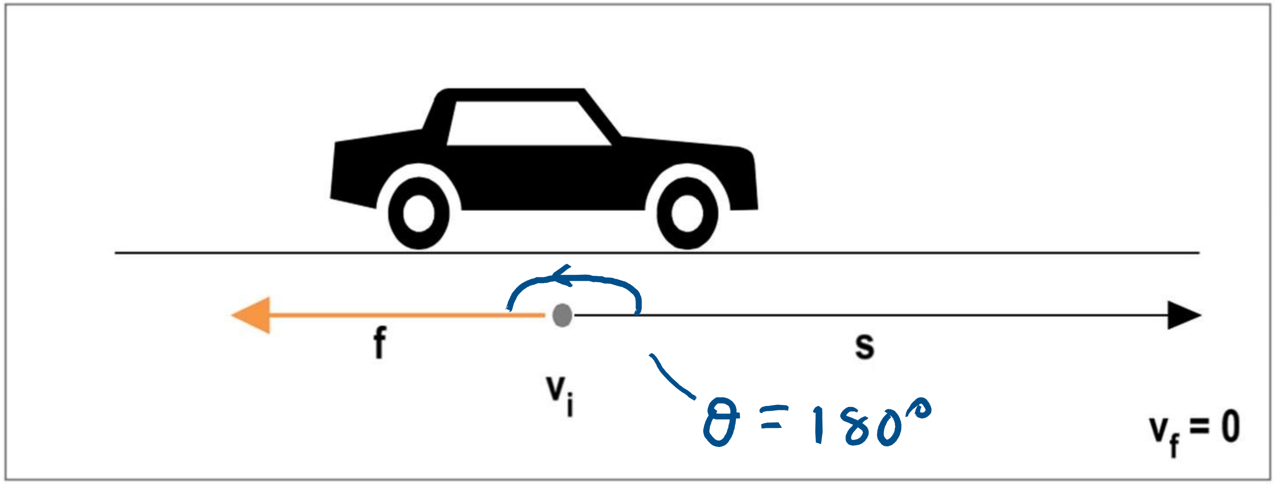

From work energy theorem,

Work done by net force is the work due to friction since friction is the only force acting.

W = fs cos 180 = -100f

Using Work energy theorem, this is equated to change in KE

Work done by net force = KE(final) – KE (initial)

$$-100f = \frac{1}{2}mv_2{}^2 - \frac{1}{2}mv_1{}^2$$

$$-100f = 0 - \tfrac{1}{2}(2000)(20)^2$$

$$f = 4000\ N$$

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$$-100f = 0 - \tfrac{1}{2}(2000)(20)^2$$

$$f = 4000\ N$$

OR

$W_n = KE(f) - KE_i$

$fs = 0 - \frac{1}{2}mu^2$

$100f = -\frac{1}{2}\ 2000\,(20^2)$

$f = -4000N$

opposes the motion

Solve this using the Work – Energy Theorem

Self-help task 6.5

A 2 kg box is pushed from rest with a horizontal force of 100 N along a horizontal track of 5.0 m. What is its final velocity at the end of the track, if $\mu = 0.7$?

Accident reconstruction

Sometimes people involved in car accidents make exaggerated claims of chronic pain due to subtle injuries to the neck or spinal column.

The likelihood of injury can be determined by finding the change in velocity of a car during the accident over a distance or time.

The larger the change in velocity, the more likely it is that the person suffered spinal injury resulting in chronic pain.

How can reliable estimates for this change in velocity be found after the fact?

In summary: work and KE

Work - Definition

Work W is the energy transferred to or from an object by means of a force acting on the object. Energy transferred to the object is positive work, and energy transferred from the object is negative work.

- If you accelerate an object to a greater speed by applying a force on the object, you increase its kinetic energy K; you performed work on the object.
- Similarly, if you decelerate an object, you decrease its kinetic energy; in this situation, the object actually did work on you (equivalent to you doing negative work).

Power

- Power is the rate at which work is done. We tend to synonymously use power for energy. When one is said to be powerful, we mean he is very energetic. In science, that is not the case; the most powerful person is the one who does work in the shortest time possible.

- At the 2014 olympics Usain Bolt ran 9.59 second thereby breaking the world record. He was the most powerful in that race because he did is work in a shortest possible time.

- Power = Work done/ Time taken = Energy/time

- $P = \frac{W}{t} = \frac{E}{t}$
- The SI unit is J/s or a **Watt** or N.m/s

- For motors and engines, power is often measured in horsepower (hp) where

  1 hp = 746 W

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

$$= \frac{J}{s} \equiv \text{Watts } (W)$$

$$P = \frac{\text{Energy}}{\text{time}} \qquad \Big| \qquad P = \frac{\text{Energy}}{t}$$

$$\text{Energy} = P\,\overset{s}{t}$$

$$= I V t$$

$$=$$

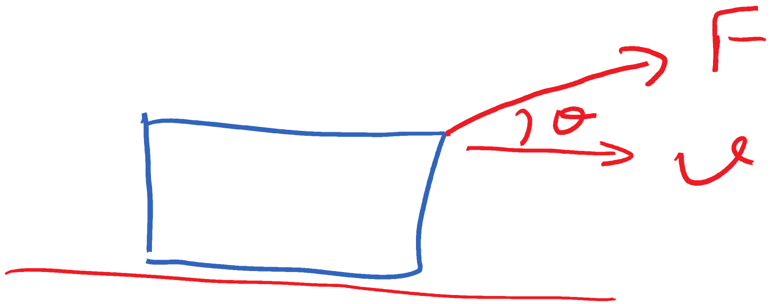
$$\text{Energy} = Wh$$

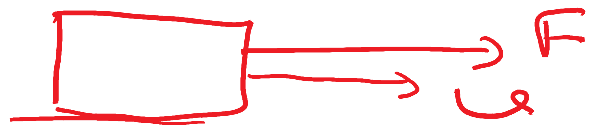
$$= 1000W\,(1h) = 1kWh \rightarrow \text{unit}$$

Power can also be expressed

$$P = F v \cos\theta \qquad [Nm/s] \;\text{''}\; J/s \;\text{''}\; W$$

where $\theta \equiv$ angle force & Velocity





$P = F v \cos\theta$

$P = F v$

Power

- Power can also be conviniently expressed in terms of velocity as
- $P = \frac{W}{t} = \frac{Fscos\theta}{t} = Fcos\theta \times \frac{s}{t}$
- But s/t = v = velocity
- Therefore
- $P = Fvcos\theta$ where θ is the angle between Force and velocity vectors.

Power Examples

- **How much power does it take to lift 10 kg up 2 meters in 2 seconds?**
  mgh = (10 kg)×(10 m/s^2)×(2 m) = 200J
  200 J in 2 seconds → 100 Watts

$P = \frac{W}{t} = \frac{200}{2s} = 100W$

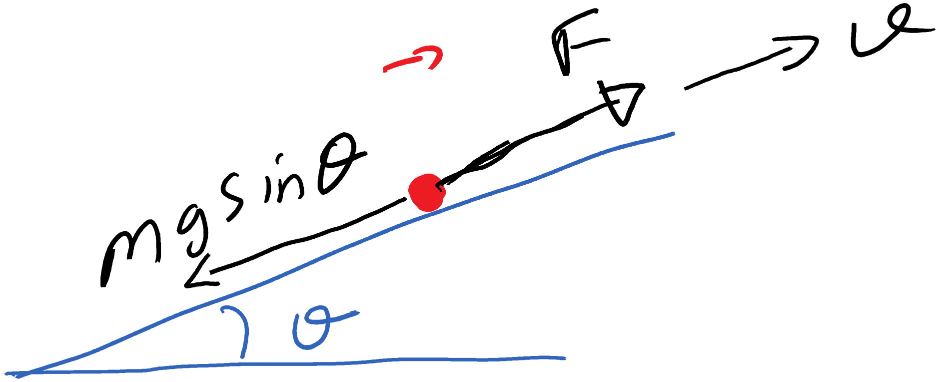
- **If you want to heat the 3 m cubic room by 10ºC with a 1000 W space heater, how long will it take?**
  We know from before that the room needs to have 360,000 J added to it, so at 1000 W = 1000 J/s this will take 360 seconds, or six minutes.

$P = E/t$

But: the walls need to be warmed up too, so it will actually take longer (and depends on quality of insulation, etc.)

Example

In a common test for cardiac function (the “stress test”), the patient walks on an inclined treadmill. Estimate the power required from a 75-kg patient when the treadmill is sloping at an angle of 12° and the velocity is 3.1 km/h.



$F = mg\sin\theta$

The angle btn F & v = 0

$\therefore P = Fv\cos\phi$

$= mg\sin 12\, v\cos 0 = 75 \times 9.8 \sin 12 \times \frac{3100}{3600}$

// 131.6 W

Example

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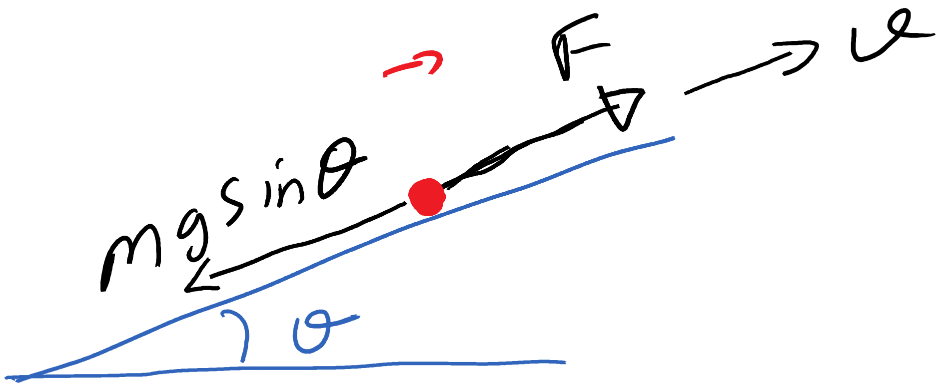

$$F = mg\sin\theta$$

Example

$P = E/t \Rightarrow E = P \times t$

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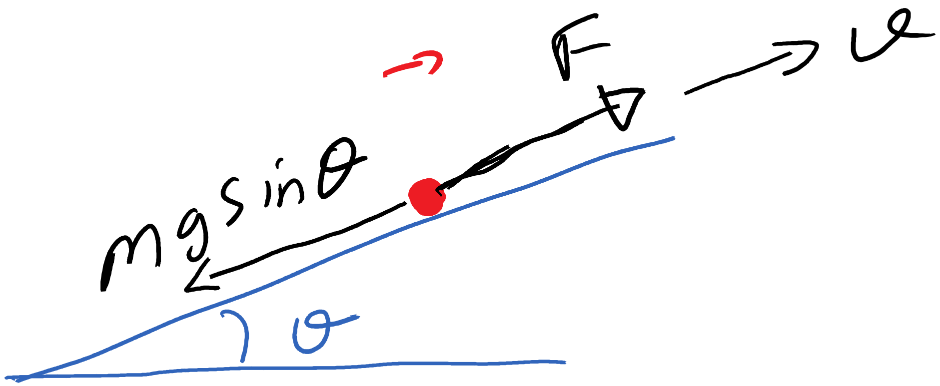


$v = \frac{3.1\,km}{h} = \frac{3.1 \times 1000\,m}{3600\,s}$

$F = mg\sin\theta$

The angle btn F & v $= 0$

$\therefore P = Fv\cos\phi$

$= mg\sin 12\, v\cos 0 = 75 \times 9.8 \sin 12 \times \frac{3100}{3600}$

$= 131.6\ W$

Efficiency is defined as the useful energy output divided by total energy input.

$$efficiency = \frac{useful\ energy\ output}{total\ energy\ input} \times 100\% \qquad (1.24)$$

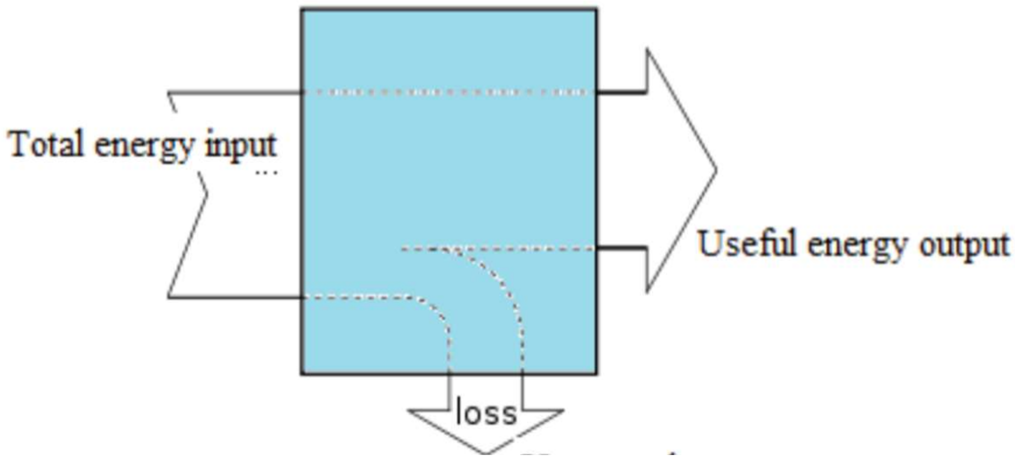
This can be also written as

$$efficiency = \frac{useful\ energy\ output}{total\ energy\ input} \times 100\% = \frac{useful\ \ power\ output \times time}{total\ \ power\ input \times time} \times 100\%$$

(1.25)

Cancelling the variable *time* in the above equation gives

$$efficiency = \frac{useful\ \ power\ output}{total\ \ power\ input} \times 100\% \qquad (1.26)$$



Example:

The input power of a car engine is 100kW. Its maximum speed is 120km/h if the drag force on it is 1500N. What is the efficiency of the car engine in this case? Where is the lost energy?

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$P = Fv$

Solution:

The total power input is $P_{in} = 100kW = 10^5 W$

The useful power output is $P_{out} = Fv = 1500 \times (120 \times 10^3 / 3600) W = 50000 W$

The efficiency of the car engine $= P_{in} / P_{out}$ =50%

Some energy is lost due to heating, sound, air drag

POTENTIAL ENERGY

- Energy possessed by an object by virtue of its position.

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  Simply let it go! If it moves, then it had PE.

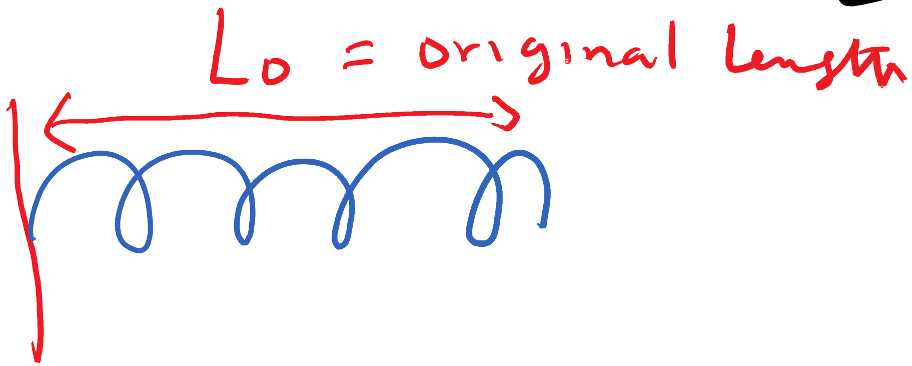
Gravitational PE (GPE)

work in lifting from ground to height $h = mgh$.

This is the GPE : $\therefore GPE = mgh$

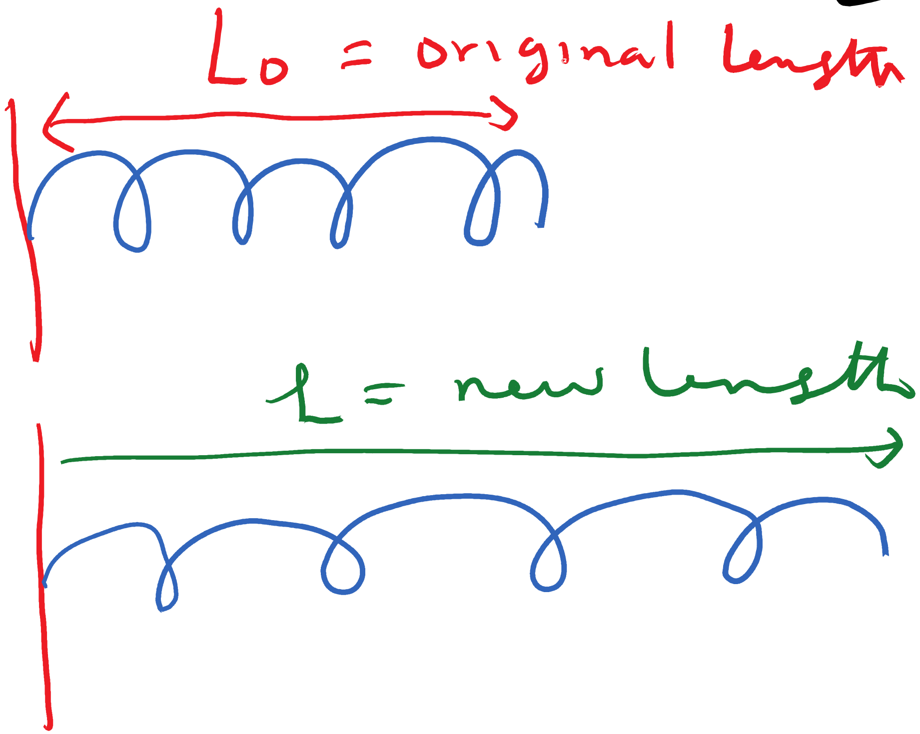
Elastic Potential Energy

EPE



Elastic Potential Energy

EPE



Work done in stretching is

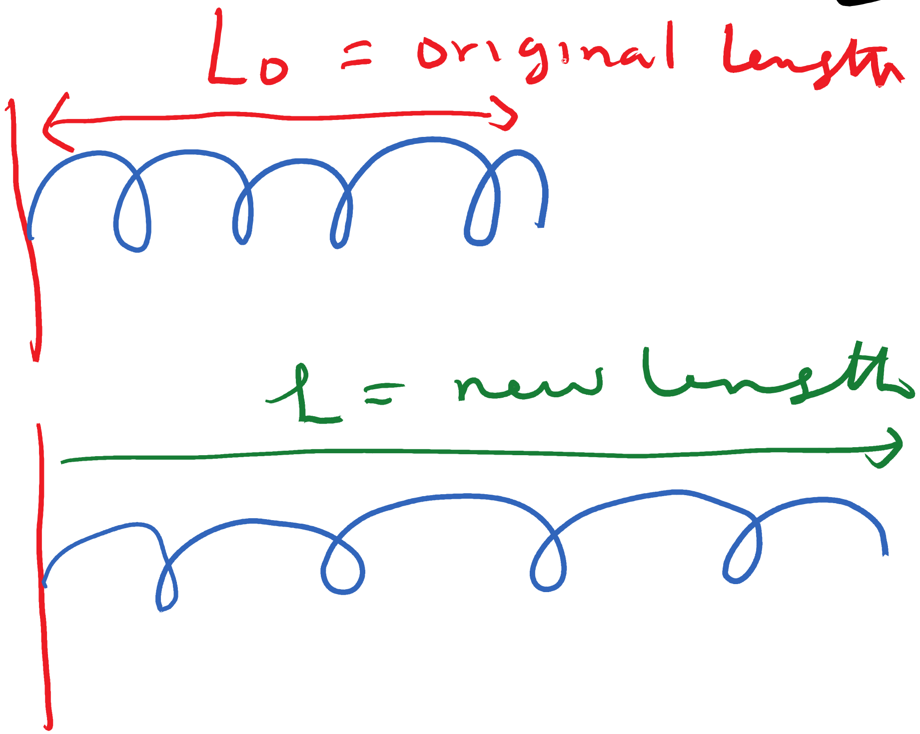
$$W = \frac{1}{2} k x^2$$

Spring Constant

extension $= \Delta L = L - L_0 = x$

Elastic Potential Energy

EPE



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$$W = \frac{1}{2}kx^2$$

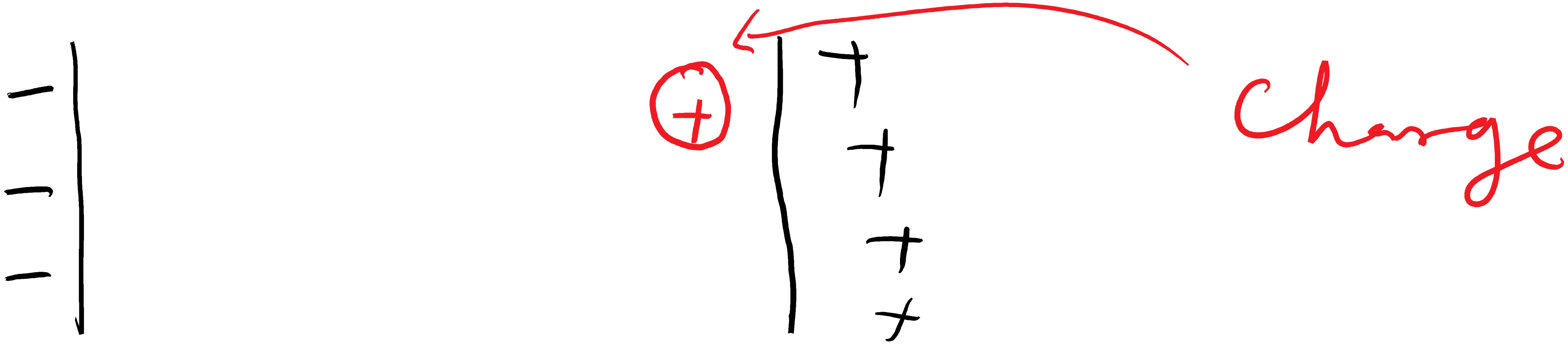
Spring Constant

extension $= \Delta L = L - L_0 = x$

$$\boxed{U = \frac{1}{2}kx^2}$$

This is the PE.

Electric potential energy

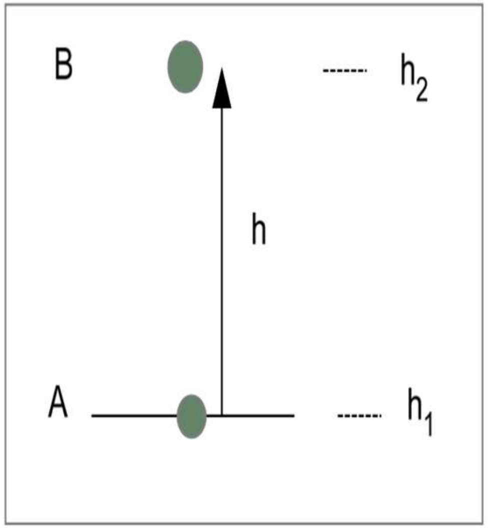


It has PE because when let go, it moves to the left. It gets repelled by +ve plate & attracted by −ve plate.

⇒ The same with magnetic materials . . . .

Potential Energy

- This is the energy possessed by an object by virtue of its position. If you lift a mass *m* from point A to point B, the object at B will acquire a gravitational potential energy (GPE).



To know whether an object has PE, just release it

wherever it is, if it moves then it has PE.

The ball at B once released will start moving, falling down.

This means it has PE. This PE is called Gravitational PE (GPE)

- If you stretch a spring and then you let it go, be virtue of its position (stretched position) it will bounce back implying it had PE. This PE is called elastic PE (EPE). If you pinch your skin and try to pull it then let it go, it moves back to its orginal state. This means it had gained EPE.
- EPE = $1/2kx^2$ (where x is the extension)

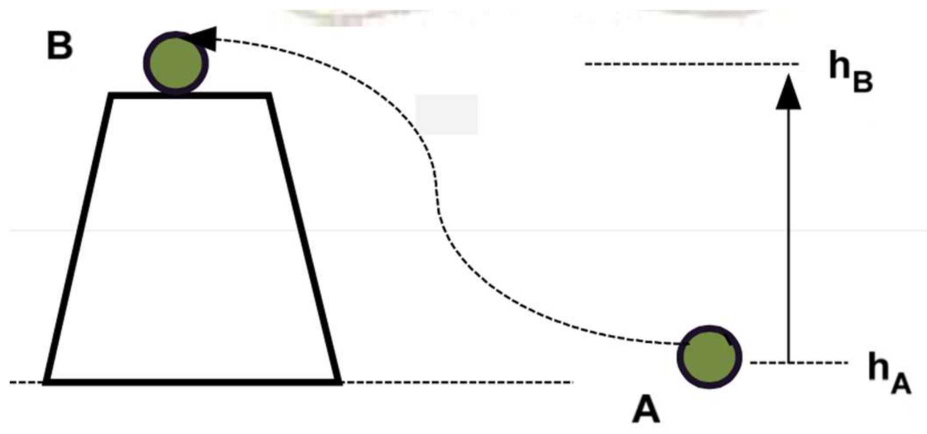
Potential Energy

- Since work is the manifestation of energy possessed in an object, if you lift the ball from A to B, the work done is F x d = mg x h = mgh (h=d=height).

- Since this is the work done to cause an object to have GPE, therefore potential energy in this case is

- PE = mgh. The unit for PE is the joule (J). Now consider this diagram:

GPE = mgh



Conservative and non-Conservative forces

- To lift the mass m from point A to point B, the work done against gravity is mgh . Similarly in lowering the mass, the work done against gravity is $-mgh$. The gravitational force is an example of what we call a **conservative force.**
- A force is said to be **conservative** if the work done in moving an object from A to B against the force is not dependent on the path taken for the movement. All you need is the vertical distance.
- An example of a **non-conservative** force is friction. The work done by the force depends on the path taken.

Law of Conservation of Energy

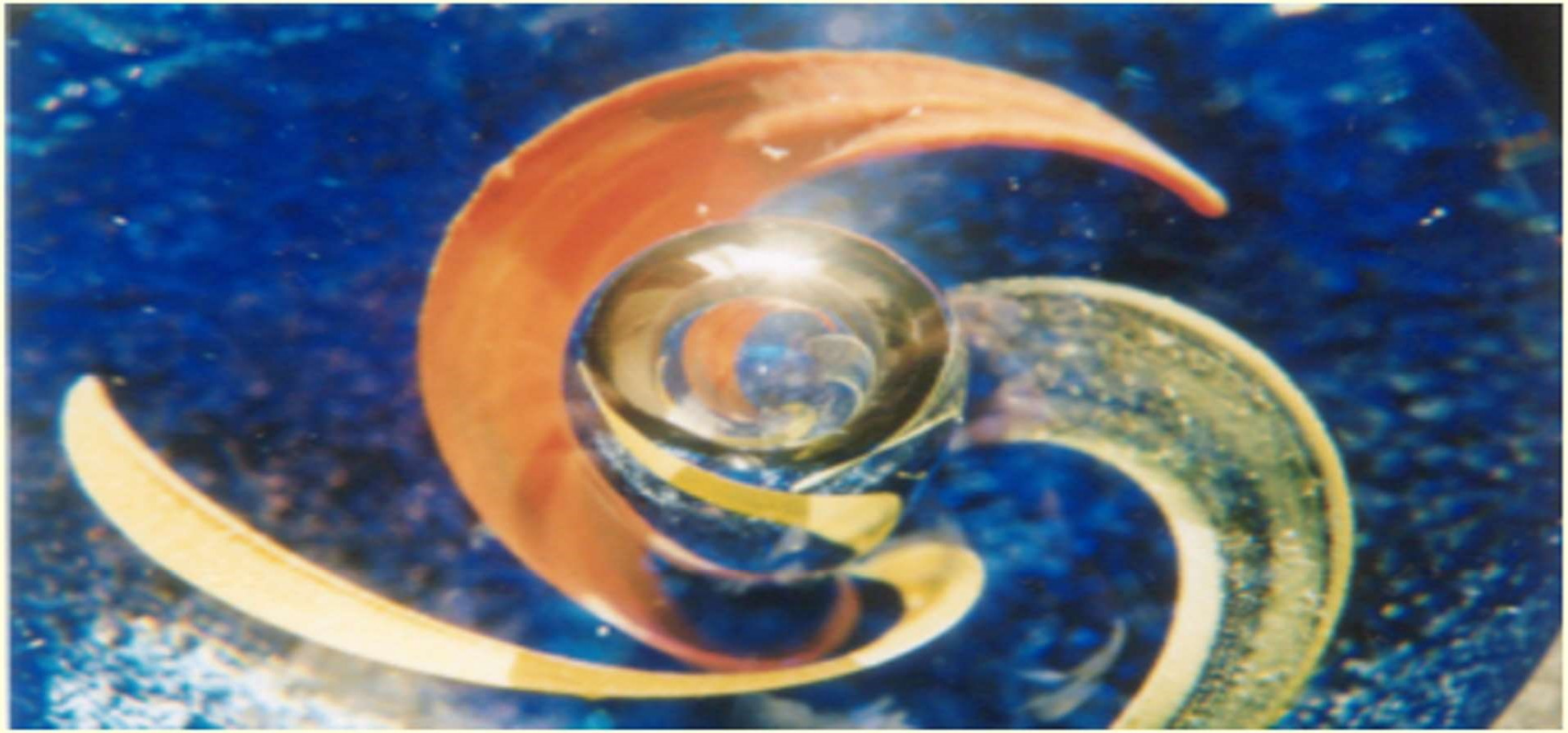
- When you keep in mind that energy is related to the ability to do work, it becomes clear that there are many other forms of energy. Coal, oil gasoline and other fuels possess energy which we call chemical energy. These can undergo chemical combustion and can do work.

- The water at a hydroelectric power station has potential energy which then is converted to mechanical energy thereby turning the turbines and producing electrical energy. This is just one of the many other energy conversions that we have in nature.

Law of Conservation of Energy

- This leads us to the concept of *energy conservation.* Energy conservation is a fundamental law of physics and is an enormously useful principle for the solution of problems.

- Therefore for a closed system, when one form of energy is converted to another form, the sum total of energy remains the same.



The Flow of Energy

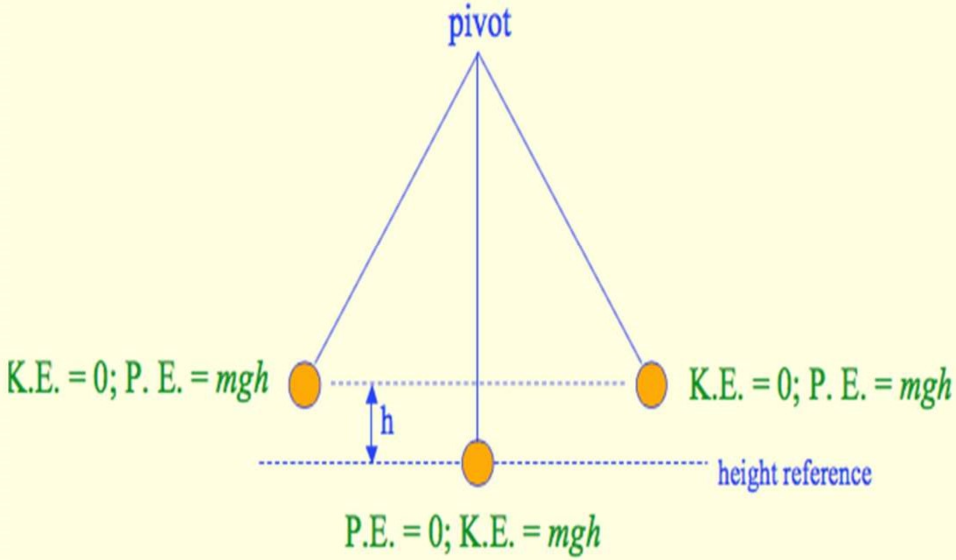
Where it comes from; where it goes

Energy is Conserved

- Conservation of Energy is different from Energy Conservation, the latter being about using energy wisely
- Conservation of Energy means energy is neither created nor destroyed. The total amount of energy in the Universe is <u>constant</u>!!
- Don't we *create* energy at a power plant?
  - No, we simply *transform* energy at our power plants
- Doesn't the sun *create* energy?
  - Nope—it *exchanges* mass for energy

Energy Exchange

- Though the total energy of a system is constant, the *form* of the energy can change
- A simple example is that of a pendulum, in which a continual exchange goes on between kinetic and potential energy

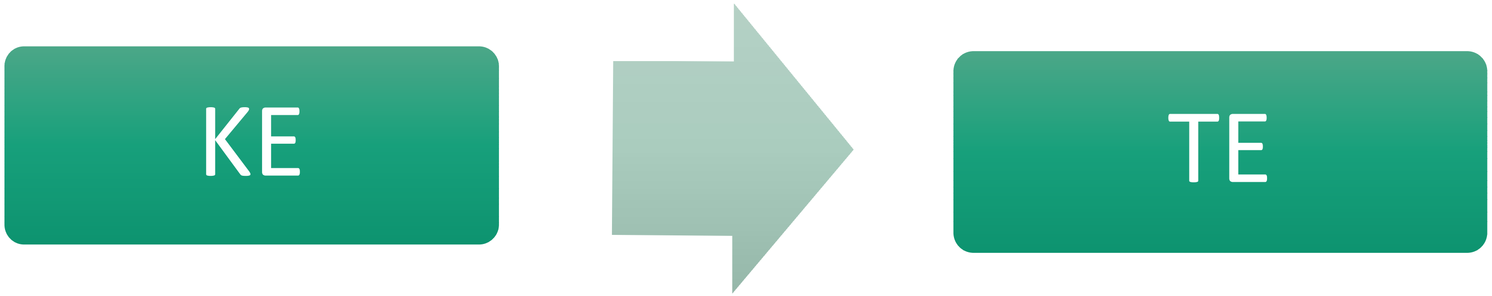


Did you know

- The sun is our primary source of energy.
- When the sun’s radiation reaches us, most of it is wasted away but some is locked up by plants through the process of photosynthesis to form chemical energy.
- When we eat the food it is then broken down through the process of respiration to give us energy that we use in the muscles, for all body functionalities.
- You can clearly see that no new energy was created but was simply converted from one form to another.

Law of Conservation of Energy

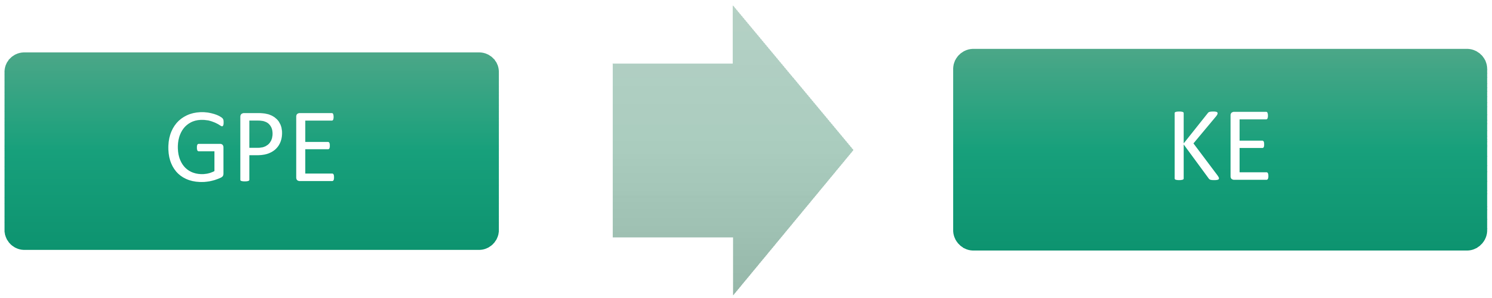
- Another example of energy conservation is when you slide a book across a table. The kinetic energy you gave to the book disappears as the book comes to rest. Yet the book has not gained GPE since the floor is level. What happened to the KE, the original energy?
- To answer this, you should investigate the temperature of the book. You will discover that the temperature has increased. This is because of friction. The original KE has been entirely converted into doing work against friction and the result is the thermal energy TE that appears between the floor and the book. In this case, the energy conservation is



$$\frac{1}{2}mv^2 = fs$$

Example - Dropping an object from height h

- If you drop an object from height h, you can work out the velocity at which it will hit the ground. This because at height h, it has PE and when it falls, all the PE is converted to KE.



$$mgh = \frac{1}{2}mv^2$$

Therefore

$$v = \sqrt{2gh}$$

Law of Conservation of Energy

- In any physical process, there are always transformations of some forms of energy into other forms of energy. The law of conservation of energy states
- **"Energy can neither be created nor destroyed. When a loss in one form of energy occurs, an equal increase occurs in other forms."**

$$\sum E_1 = \sum E_2$$

or

$$KE_1 + PE_1 + TE_1 = KE_2 + PE_2 + TE_2$$

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$$KE_1 + PE_1 + \overset{0}{\cancel{TE}_1} = KE_2 + PE_2 + TE_2$$

This is energy conservation involving KE, PE and work against friction, the heat energy TE. TE_1 in this case is zero because, the object has not yet moved so the displacement is zero so that $TE_1 = fs = fx0 = 0$.

Thus the conservation of energy

$$PE_1 + KE_1 + TE_1 = PE_2 + KE_2 + TE_2$$

$$\boxed{PE_1 + KE_1 = PE_2 + KE_2 + TE_2}$$

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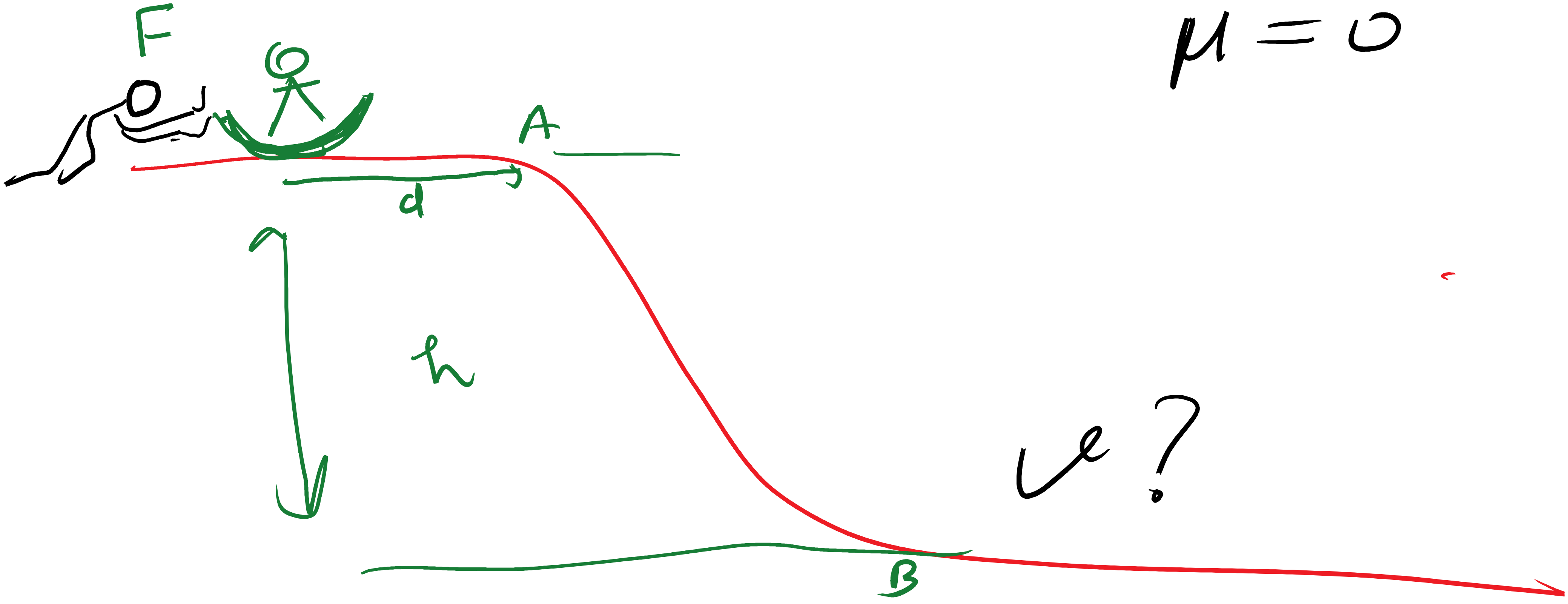
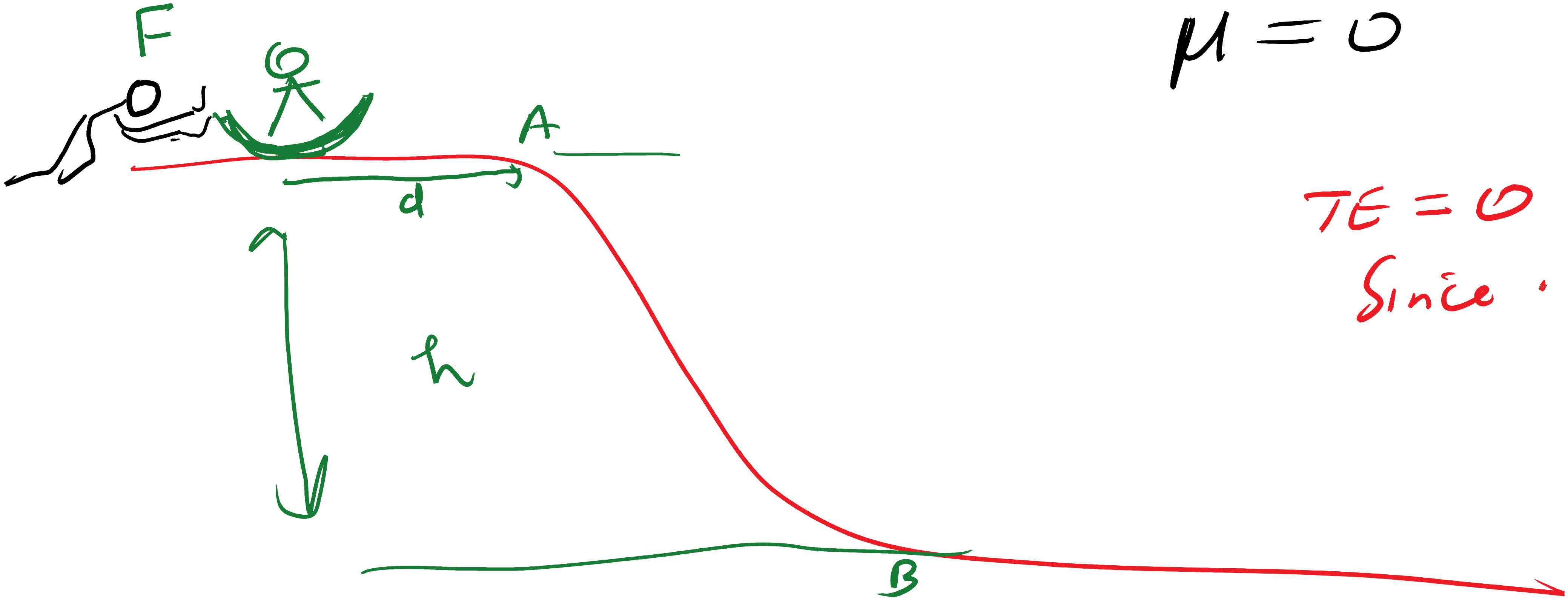


$\mu = 0$

v ?



$\mu = 0$

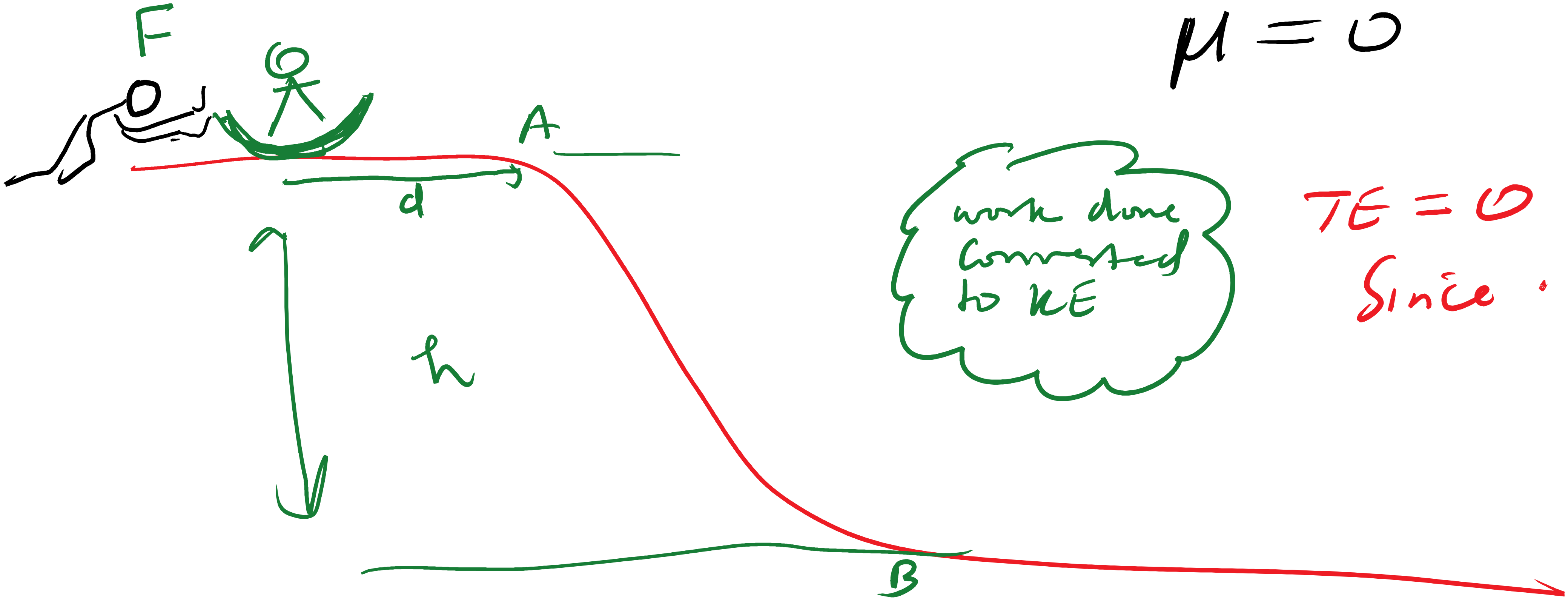
$TE = 0$

Since .

$PE_A + KE_- = KE_B + PE_B$

$mgh_A + Fd = \frac{1}{2}mv_B^2 + mgh_B$

$\mu = 0$



work done converted to KE

$TE = 0$

Since .

$$PE_A + KE_{\_} = KE_B + PE_B$$

$$mgh_A + Fd = \frac{1}{2} m v_B^2 + mgh_B$$

$$mgh + Fd = \frac{1}{2} m v_B^2$$

Thus the conservation of energy

$$PE_1 + KE_1 + TE_1 = PE_2 + KE_2 + TE_2$$

$$(PE_2 - PE_1) + (KE_2 - KE_1) + (TE_2 - TE_1) = 0$$

$$\Delta PE + \Delta KE + \Delta TE = 0$$

0

$$\boxed{\Delta PE + \Delta KE + fs = 0}$$

Cons

EXAMPLE 6.4: A 900 kg car is moving on a horizontal road at 20 m/s when its brakes are applied and the car skids to a stop in 30 m. Use the concept of work and energy to find the frictional force between the car's tyres and the road. Assume a horizontal road.

SOLUTION

We write the energy conservation law

$$PE_1 + KE_1 + \cancel{TE}_1 = PE_2 + KE_2 + TE_2$$

$$0 + \frac{1}{2}mv_o{}^2 + 0 = 0 + 0 + fs$$

$$\frac{1}{2}mv_o{}^2 = fs$$

$$\therefore f = {\frac{1}{2}mv_o{}^2}\Big/{s} = 6000 \text{ N}$$

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$\boxed{KE} \rightarrow \boxed{TE}$

$$\frac{1}{2}mv^2 = fs$$

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Work - Energy Th

$W = \Delta KE$

$fs = \frac{1}{2}mv_f^2 - \frac{1}{2}mu^2$

$fs = 0 - \frac{1}{2}mu^2$

$fs = -\frac{1}{2}\,900\,(20)^2$

$f = -6000\,N$

opposing

Solve this

Self-help task 6.7

A 50 kg crate falls off the roof of a building. By the time it hits t the street 40 m below, it is moving at a speed of 20 m/s. Using the energy concepts find the average force of air drag during the fall.

The energy conversion looks like

GPE = KE + TE

Solve this

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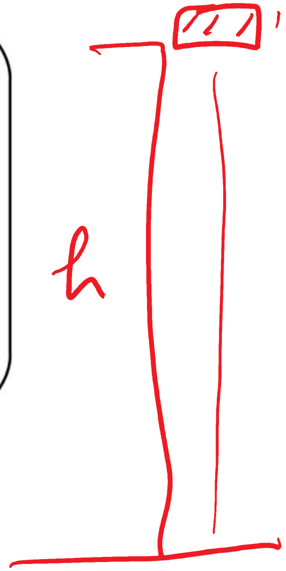


The energy conversion looks like

GPE = KE + TE

$m = 50\,kg$

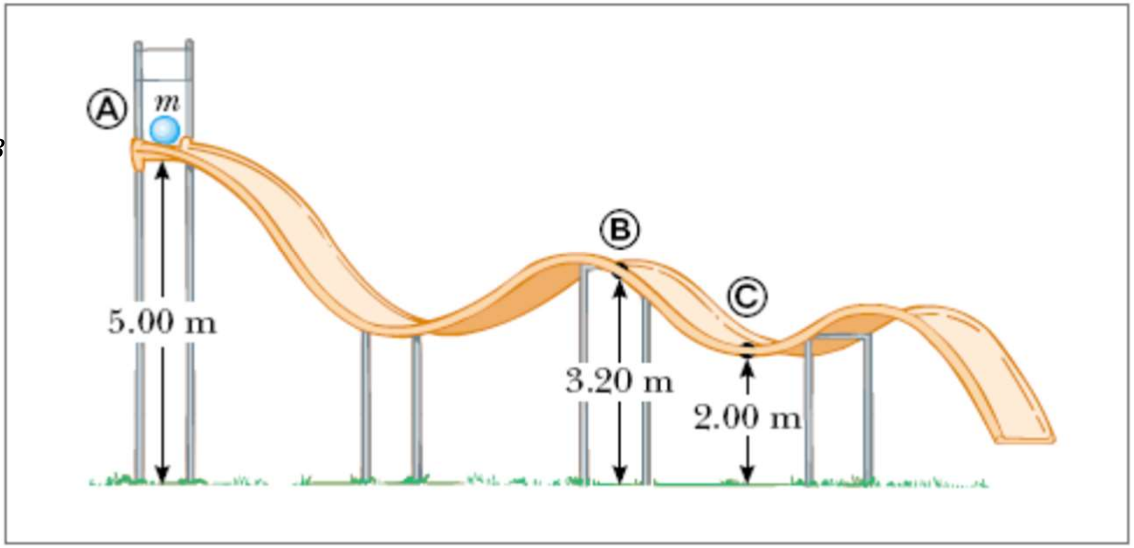
$h = 40m$

$v = 20m/s$

$f = ?$

$$mgh = \frac{1}{2}mv^2 + fh$$

EXAMPLE 6.4: A particle of mass $m = 5.00$ kg is released from point **A** and slides on the frictionless track shown in Figure 6.8. Determine (a) the particle's speed at points **B** and **C** and (b) the net work done by the gravitational force in moving the particle from **A** to **C**.



$$PE_A + KE_A + TE_A = PE_B + KE_B + TE_B$$

But no heat due to work done against friction is generated at A since it has not moved as yet, therefore $TE_A = 0$

$$mgh_A + 0 + 0 = mgh_B + \frac{1}{2}mv_B{}^2 + 0$$

Substituting the variables gives

v_B= 5.44 m/s

You can do the same for velocity at C . The answer is 7.67 m/s

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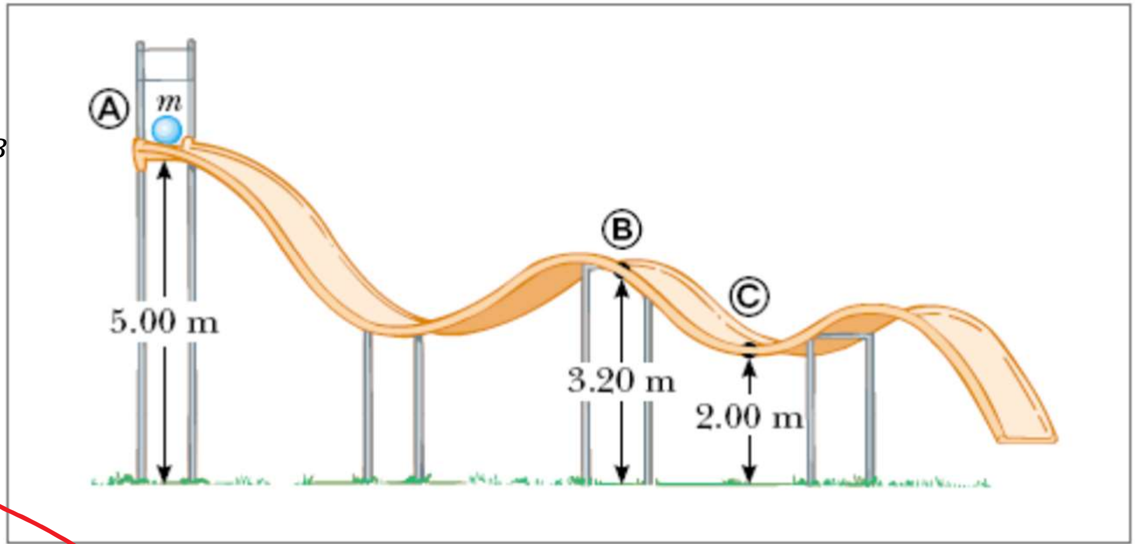

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Substituting the variables gives

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$$\frac{1}{2}mv_B^2 = mg(h_A - h_B)$$

$$v_B = \sqrt{2g(h_A - h_B)}$$

$$= \sqrt{2(9.8)(1.8)}$$

You can do the same for velocity at C . The answer is 7.67 m/s

Conservation of energy faith in Scie